IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Filed	:	Herewith
For	:	HEAD VIBRATION DETECTION DEVICE AND METHOD
Docket No.:		S01.12-0543

TRANSMITTAL LETTER

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The following paper(s) and/or fee(s) are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" addressed to BOX PATENT APPLICATION, Assistant Commissioner for Patents, Washington, D.C. 20231:

1. Our checks in the amount of $760 and $40.00
2. Fee Calculation Sheet (in duplicate)
3. Patent Application comprising the following pages:
   - 1 Abstract
   - 9 ~~14~~ Specification
   - 4 Claims
4. 8 Sheets of drawings
5. Executed Declaration (2 pages)
6. Executed Assignment and Recordation Form Cover Sheet
7. Information Disclosure Statement with PTO Form 1449 and (4 references)

Under 37 CFR § 1.136(a)(3), applicant(s) hereby authorize(s) for any future reply, the incorporation of any required petition for extension of time for the appropriate length of time and authorize the charging of fees under § 1.17 to deposit account 23-1123.

Respectfully submitted,

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PATENT APPLICATION OF

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ENTITLED

HEAD VIBRATION DETECTION DEVICE AND METHOD

Docket No. S01.12-0543

HEAD VIBRATION DETECTION DEVICE AND METHOD

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority to U.S. Provisional Application Serial No. 60/121,157, filed February 22, 1999 and entitled "USING A PZT MICROACTUATOR TO SENSE HEAD/DISC CONTACT".

FIELD OF THE INVENTION

The present invention relates to a data storage system. In particular, the present invention relates to an assembly for monitoring head vibration for a data storage system.

BACKGROUND OF THE INVENTION

Disc drives are used to store digitally encoded information on discs. Transducer elements read data from and write data to disc supported for rotation by a spindle motor. Transducer elements are supported above the disc surface by a head suspension assembly. Heads are positioned relative to data tracks via a voice coil motor. Disc drive density is increasing necessitating increased head positioning accuracy. Microactuators are used with a voice coil motor for adjusting head position for track placement. Microactuators include piezoelectric transducers on a head suspension assembly which receive a signal command from a controller to actuate the head.

Surfaces of the discs include asperities and other defects due to variations in the manufacturing process or created during shipping and handling or operation and use of the disc drive. During read write operations a head may contact asperities on the disc surface interfering with read/write operations. Contact between the head and disc surface can damage the disc surface and result in permanent data loss for a write command. Prior disc drives incorporate acoustic

emission sensors attached to an E-block arm to determine head-disc contact. Sensor attached to an E-block arm sense head -disc contact for some head on the E-block however its difficult to distinguish which head-disc interface is contacting. The present invention addresses these and other problems, and offers other advantages over prior art.

SUMMARY OF THE INVENTION

The present invention relates to a disc drive including a transducer supported on the head suspension assembly to induce a transducer signal in response to head vibration. The transducer signal is level detected to output a level detected signal indicative of head vibration. These and other beneficial features of the present invention will become apparent upon review of the following FIGS. and related explanations.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective illustration of an embodiment of a disc drive.

FIG. 2 is a schematic illustration of head vibration modes.

FIG. 3 is an illustration of an embodiment of a head vibration detector of the present invention.

FIG. 4 is an illustration of a threshold level detection for a transducer signal.

FIG. 5 illustrates a vibration signal for slider "take-off"

FIG. 6 is a schematic illustration of a process controller coupled to a detector for executing a write recovery algorithm for head vibration.

FIG. 7 is a schematic of control circuitry for a disc drive operably in a detection mode and an actuator mode.

FIG. 8 is a top view of an embodiment of a suspension mounted transducer for operation of the present invention.

FIG. 9 is a side view of the suspension mounted transducer of FIG. 8.

FIG. 10 is a top view of an alternate embodiment of a suspension mounted transducer for operation of the present invention.

FIG. 11 is a flow chart illustrating operation in an actuation mode and a detection mode.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1. illustrates a disc drive 50 including a chassis 52, discs 54, and actuator assembly 56. Discs 54 are rotationally coupled to chassis 52 via a spindle motor (not shown) for rotation, as illustrated by arrow 58. Actuator assembly 56 rotationally supports heads 60 as illustrated by arrow 62 for reading and/or writing data to and from discs 54. Heads include transducer elements supported by a slider. For proximity or near proximity recording the slider flies above the disc surface. Rotation of the disc creates an air flow under an air bearing surface of the slider so that the slider "takes off" from the disc surface. Vibration or shock to the disc drive or asperities in the disc surface can cause the slider to contact or slam into the disc surface during read and write operations. Head disc contact can damage the disc surface and can interfere with a read/write command resulting in permanent data loss for a write command.

FIG. 2 diagrammatically illustrates a slider 70 supported relative to a flexible head suspension assembly 72 illustrated diagrammatically in FIG. 2. Head disc contact causes the slider to vibrate or move. Modes of vibration or movement of the slider 70 include

bending mode vibration and torsion mode vibration. Vibration at the natural frequency of the slider or air bearing amplifies the motion of the slider. The present invention relates to a head vibration detector on the head suspension assembly for detecting vibration of the supported head or its air bearing.

In the embodiment illustrated in FIG. 3, head vibration is detected by transducer 102 supported on a head suspension assembly and detector 104. Opposed terminals 106, 108 of the transducer 102 are orientated so that vibration or movement of the transducer along the detection axis 110 induces a transducer signal or voltage signal across terminals 106, 108. The transducer 102 can be orientated for detecting various vibration modes of the head or air bearing.

As shown in FIG. 3, detector 104 receives a transducer signal and outputs a level detected signal indicative of head vibration as illustrated by block 112 as will be explained. In the embodiment illustrated in FIG. 3, detector 104 includes a filter 116, an amplifier 118 and level detector 120. The transducer signal is filter to pass vibration mode frequencies for detecting at least one vibration mode. In one embodiment, filter 116 passes vibration mode frequencies for at least one of torsion or bending mode vibration. The signal is amplified by amplifier 118 and is passed through level detector 120 to output the level detected signal indicative of the vibration mode of the head. In particular, as shown in FIG. 4, the level detector 120 passes a threshold signal amplitude 122 for transducer signal 124 to output a level detected signal indicative of head vibration.

The head vibration detector can be used for testing head disc contact for design analysis or for

drive diagnostics. For example, detector can be used for mapping drive asperities, bad disc sectors or analyzing handing damage. Thus the level detector 120 detects a threshold signal amplitude measuring head disc contact. Alternatively, the head vibration detector can be used for measuring take-off velocity for design analysis as illustrated in FIG. 5. As shown, prior to "take-off" the level detected signal amplitude 126 is large indicative of the vibrational motion of the slider and air bearing and at "take-off" signal amplitude 128 is reduced.

The head vibration detector can be implemented for write operations as illustrated in FIG. 6. As previously explained, contact or interference between the head and disc during a write operation can interfere with write operations resulting in permanent loss of the write data since once the write command is executed, the data is no longer available in drive memory. Verification of the write data by a readback process where the drive reads back the data from the disc surface to confirm the integrity of the data slows operation of the disc drive.

For write process control, detector 104 outputs a level detected signal 112 for controlling write operations. Thus, as illustrated in FIG. 6, for write operations, drive controller 130 executes a write command 132 to write data to the disc surface as illustrated by block 134. As illustrated schematically, during write operations, the level detected signal is monitored by process controller 136. Process controller is configured to receive the level detected signal from detector 104 and execute a recovery algorithm to rewrite the data in drive memory to assure that the data in drive memory is not lost or corrupted due to vibration

or head contact. Transducer 102 can be a piezoelectric or electrostatic transducer for producing a transducer signal proportional to mechanical movement of the head suspension assembly 72 induced by head vibration.

In one embodiment, the transducer operates between a detection mode and an actuator mode. In the detection mode, the transducer is used to detect head vibration as previously explained, and in the actuator mode, the transducer receives a signal to move or actuate the head. FIG. 7 schematically illustrates process control circuitry for a disc drive operable between a detection mode and an actuator mode. For read/write operations, drive circuitry 130 provides a position signal to servo control processor 140 to operate voice coil motor 142 for head placement and provides a read write command to heads. As shown, transducer 102 is coupled to the suspension assembly of the heads so that vibration of the heads strains the transducer to produce a transducer signal. In the detection mode, detector 104 receives the transducer signal and outputs a level detected signal indicative of head vibration. In the actuation mode, a microactuator controller 144 transmits a signal to the transducer 102 to adjust the dimensions of the transducer 102 providing for fine head placement capabilities.

FIGS. 8-9 schematically illustrate an embodiment of a suspension based transducer 102 configured to laterally move heads as illustrated by arrow 150 in an actuation mode and configured to detect head vibration in the detection mode. As shown, transducer 102 is aligned so that opposed terminal are formed between upper and lower terminal plates 154, 156 shown in FIG. 9 to provide a potential or voltage along a vertical axis 158 between terminals 154, 156. A

potential across terminal plates 154, 156 provides mechanical movement along a transverse axis to axis 158, or length of transducer 102 between opposed ends 160, 162.

In the embodiment shown, opposed ends 160, 162 of transducer 102 flexibly couple a first suspension portion 72-1, rigidly connected to an actuator block illustrated diagrammatically, and a second suspension portion 72-2 supporting the heads 60 so that when a transducer signal is supplied to opposed terminals 154, 156, the length between ends 160, 162 expands and contracts depending upon the direction of the signal to laterally shift the position of the second suspension portion 72-2 relative to the first suspension portion 72-1 to actuate the heads as illustrated by arrow 150.

In the detection mode, opposed terminal plates 154, 156 are aligned so mechanical movement of the transducer 102 induces a potential across terminals 154, 156 for detecting vibration modes including torsion and bending modes of the head or its air bearing. As previously explained, the signal is filtered to pass a vibration mode frequency and level detected to output a level detected signal indicative of vibration.

FIG. 10 is a top plan view schematically illustrating an alternate embodiment of a suspension based transducer configured to microactuate a head as illustrated by arrow 150 in an actuation mode and aligned to induce a transducer signal for detecting head vibration in the detection mode. As shown, transducer terminals 170, 172 are aligned transverse to vertical axis 158 and the transducer is connected in longitudinal alignment along its length with a portion of the suspension assembly. The suspension portion is structurally designed to bend as illustrated by arrow

180 relative to a fixed portion to move the head in the actuation mode. Similarly vibration or mechanical movement of the head induces a transducer or voltage signal across terminals 170, 172 which is level detected to output a signal indicative of head vibration.

FIG. 11 is a flow chart illustrating operation in an actuation mode and a detection mode. As shown in the actuation mode, a microactuator controller 144 transmits a signal to the transducer 102 to move the head as illustrated by block 192. Operation continues as illustrated by line 194 until done as illustrated by block 196. For operation in the detection mode, the detector 104 detects a transducer signal as illustrated by block 198 and the transducer signal is level detected to output a level detected signal as illustrated in block 200. Detection operation continues as illustrated by line 202 until done 204.

A disc drive including a transducer 102 supported on the head suspension assembly 72 to induce a transducer signal in response to head vibration. The transducer signal is level detected to output a level detected signal 112 indicative of head vibration.

It is to be understood that even though numerous characteristics and advantages of various embodiments of the present invention have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the invention, this disclosure is illustrative only, and changes may be made in detail, especially in matters of structure and arrangement of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. For example, the particular elements may vary depending on the particular

application while maintaining substantially the same functionality without departing from the scope and spirit of the present invention. In addition, although the preferred embodiment described herein is directed to a magnetic disc drive system, it will be appreciated by those skilled in the art that the teachings of the present invention can be applied to other systems, like an optical system, without departing from the scope and spirit of the present invention.

WHAT IS CLAIMED IS:

1. A disc drive comprising:

a head suspension assembly supporting a head;

a transducer supported on the head suspension assembly to induce a transducer signal in response to head vibration; and

a detector receiving the transducer signal and outputting a level detected signal indicative of head vibration.

2. The disc drive of claim 1 wherein the level detected signal is indicative of head-disc contact.

3. The disc drive of claim 1 wherein the detector includes a frequency filter.

4. The disc drive of claim 3 wherein the frequency filter is configured to pass at least one of a bending mode or torsion mode frequency.

5. The disc drive of claim 1 wherein the transducer is a piezoelectric material.

6. The disc drive of claim 1 wherein the transducer is an electrostatic transducer.

7. The disc drive of claim 1 and further comprising:

a process controller coupled to the detector and configured to receive an outputted level detected signal and output a process command to reexecute the write command in drive memory.

8. The disc drive of claim 1 and further comprising:

a microactuator controller coupled to the transducer and configured to transmit a signal to the transducer to move the head.

9. The disc drive of claim 1 wherein the disc drive includes a plurality of head suspension assemblies and including a transducer coupled to each head suspension assembly.

10. The disc drive assembly of claim 1 wherein the transducer is configured to operate between a detection mode and a actuation mode, in the detection mode, the transducer detecting head vibration and in the actuation mode the transducer moving the head.

11. The disc drive assembly of claim 12 including:

a microactuator controller coupled to the transducer and configured to operate the transducer in the actuation mode.

12. A method for operating a disc drive comprising steps of:

(a) providing a transducer supported on a head suspension assembly configured to generate a transducer signal indicative of head vibration; and

(b) detecting the transducer signal and outputting a level detected signal indicative of head vibration.

13. The method of claim 12 wherein the transducer is a piezoelectric transducer.

14. The method of claim 12 and further comprising the step of:

(c) transmitting a signal to the transducer to move the head.

15. The method of claim 12 and further comprising steps of:

(c) transmitting a command to rewrite a write command in drive memory in response to a level detected signal indicative of head vibration.

16. The method of claim 12 and comprising the step of

(c) filtering the transducer signal for vibration frequencies of the head.

17. The method of claim 12 wherein the disc drive includes a plurality of head suspension assemblies and further comprising:

(c) detecting vibration for each of the plurality of head suspension assemblies.

18. The method of claim 12 including a microactuator controller coupled to the transducer and configured to transmit a signal to the transducer to move the head and comprising the step of:

(c) selectively operating the disc drive in a detection mode and an actuation mode, in the detection mode the transducer detecting head vibration and in the

actuation mode, the transducer moving the head.

19. A disc drive assembly comprising:

a head suspension assembly supporting a head; and

means for detecting head vibration.

HEAD VIBRATION DETECTION DEVICE AND METHOD

ABSTRACT OF THE DISCLOSURE

A disc drive including a transducer supported on the head suspension assembly to induce a transducer signal in response to head vibration. The transducer signal is level detected to output a level detected signal indicative of head vibration. A method for detecting head vibration via a transducer on a head suspension assembly. The transducer on the head suspension assembly operating between a detection mode and an actuator mode for selectively detecting vibration and actuating the head.

FIG. 1

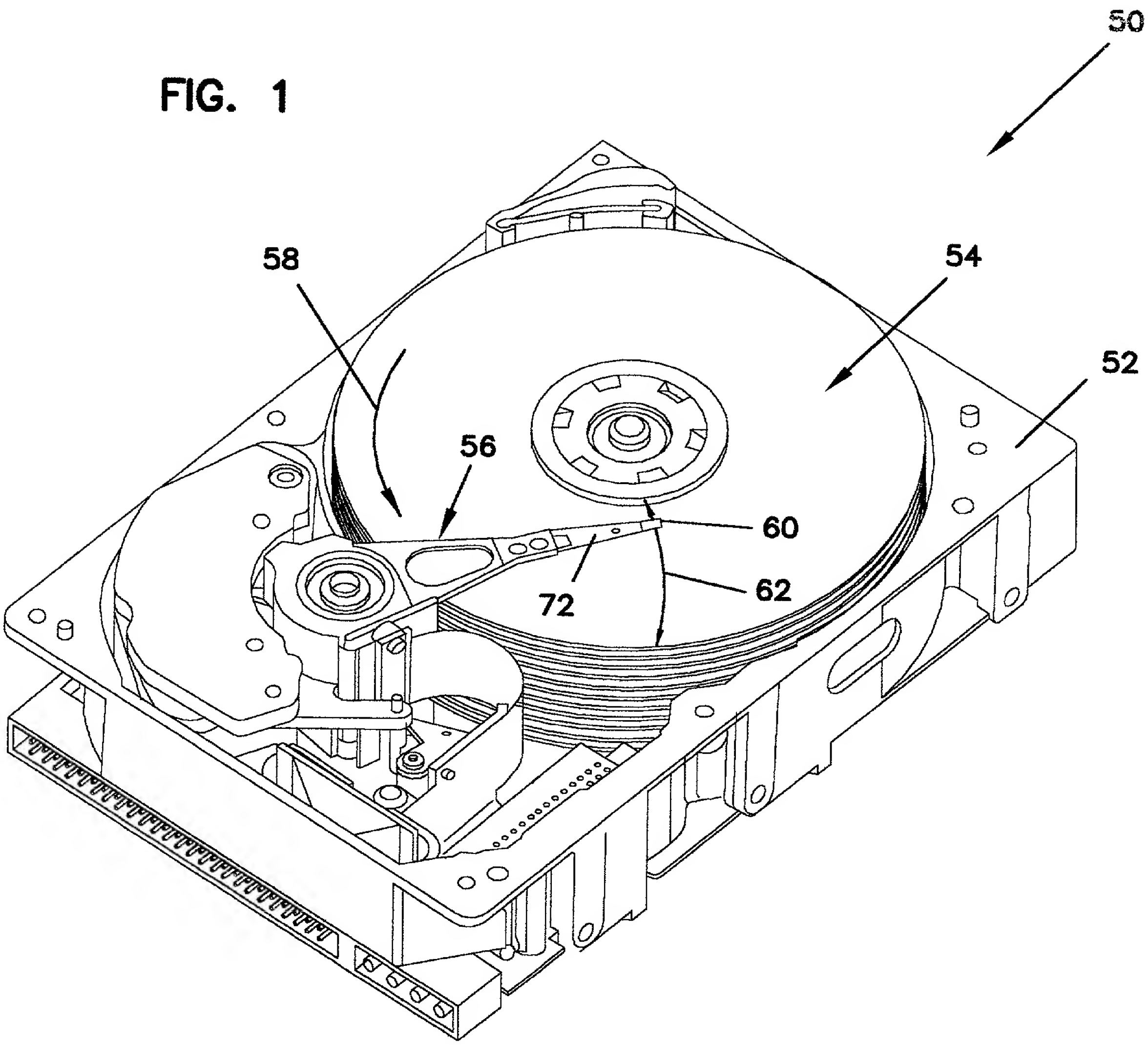


FIG. 2

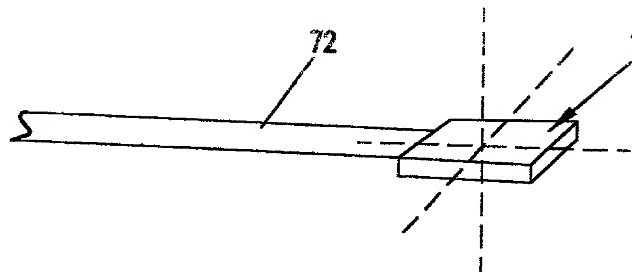

72
70

FIG. 3

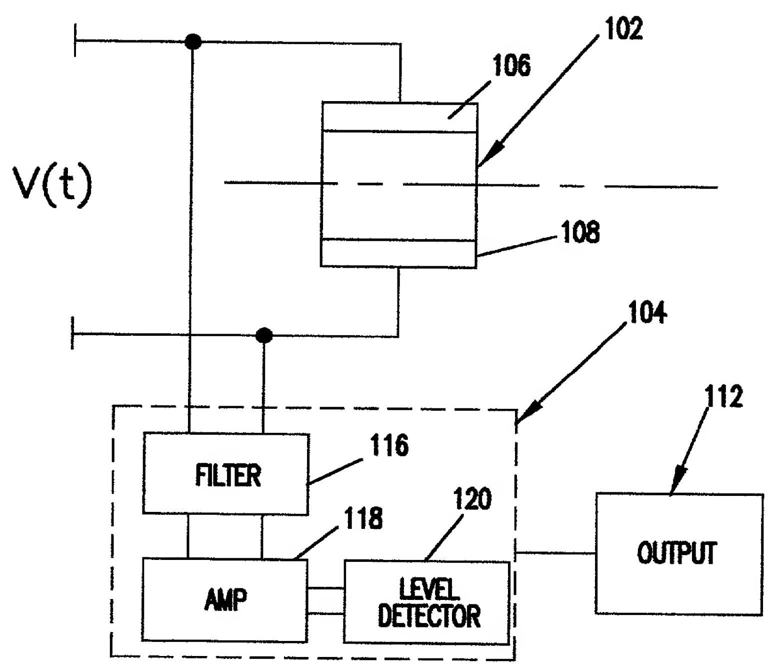
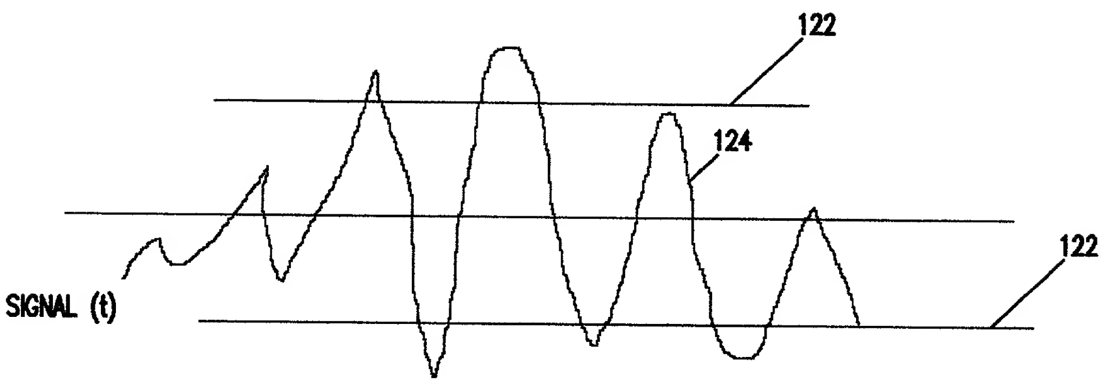
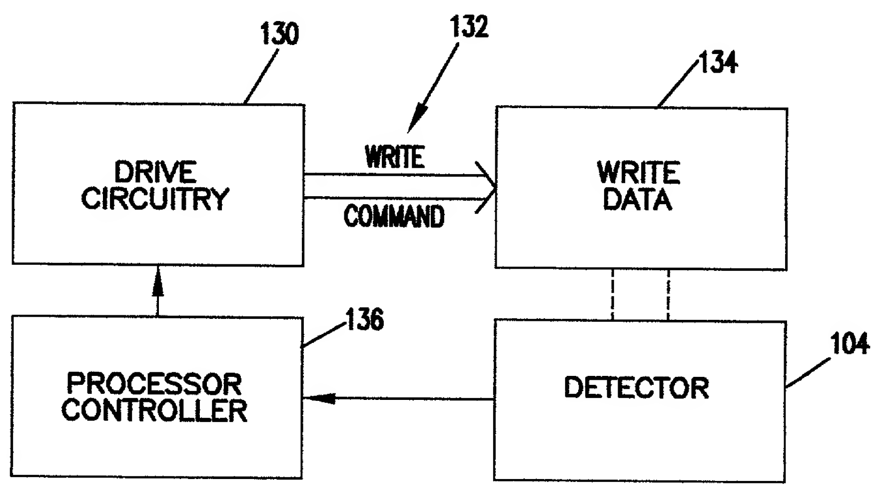

102
106
V(t)
108
104
112
FILTER
116
120
118
OUTPUT
AMP
LEVEL DETECTOR

FIG. 4



122
124
122
SIGNAL (t)

FIG. 6



130
132
134
DRIVE CIRCUITRY
WRITE
COMMAND
WRITE DATA
136
104
PROCESSOR CONTROLLER
DETECTOR

FIG. 5

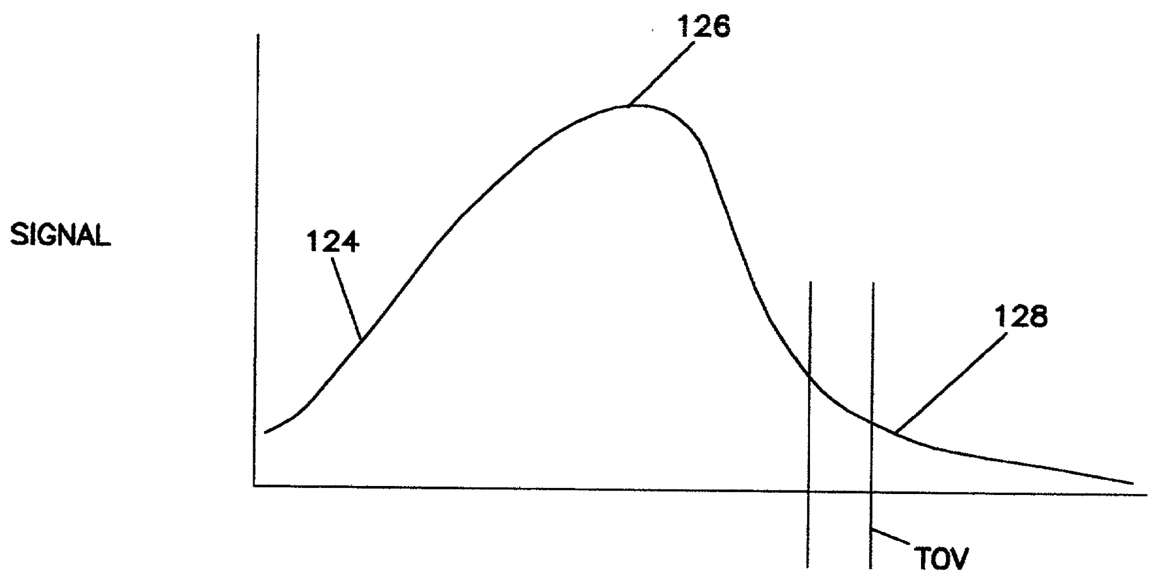
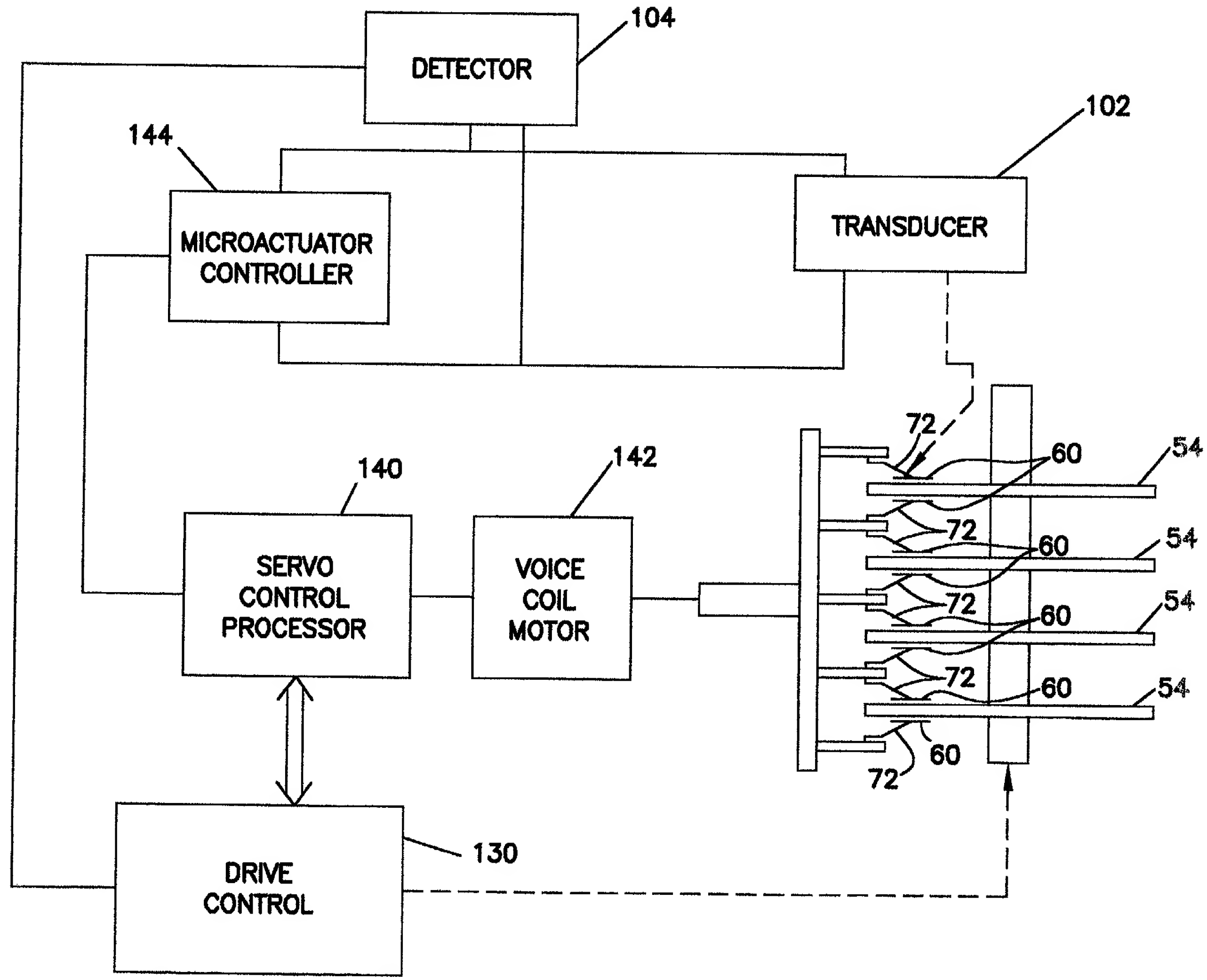
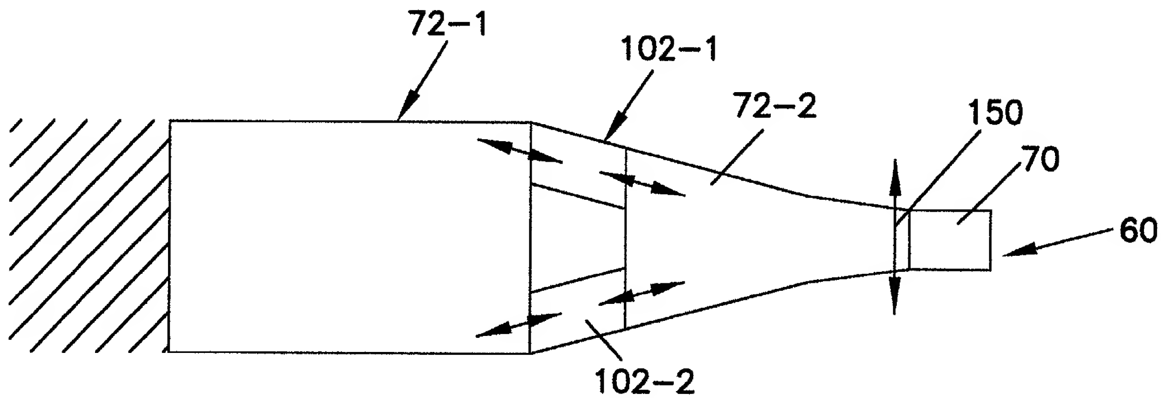


FIG. 7



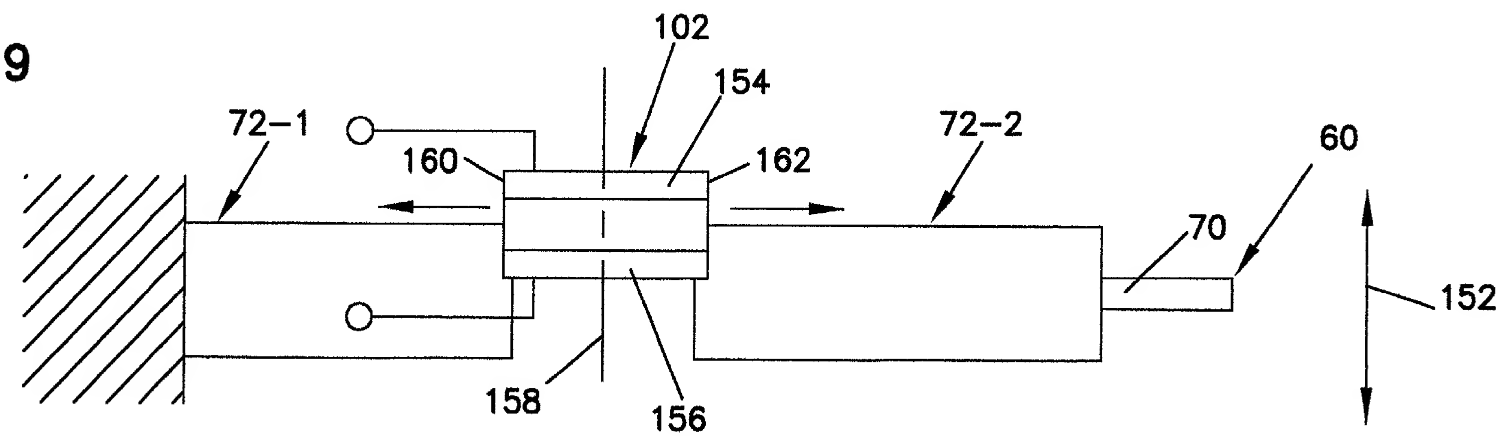
DETECTOR
104
144
MICROACTUATOR
CONTROLLER
102
TRANSDUCER
72
60
54
140
142
SERVO
CONTROL
PROCESSOR
VOICE
COIL
MOTOR
72
60
54
72
60
54
72
60
54
60
72
DRIVE
CONTROL
130

FIG. 8



72-1
102-1
72-2
150
70
60
102-2

FIG. 9



102
154
72-1
160
162
72-2
60
70
152
158
156

FIG. 10

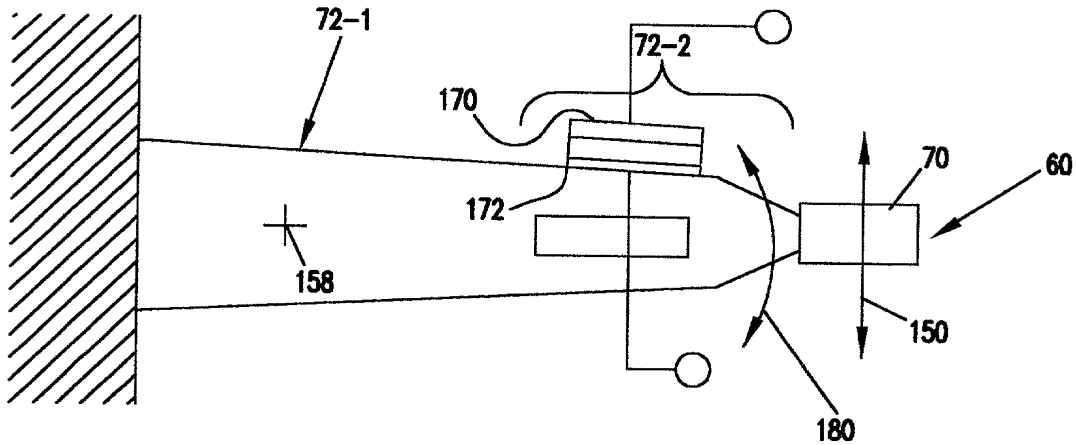
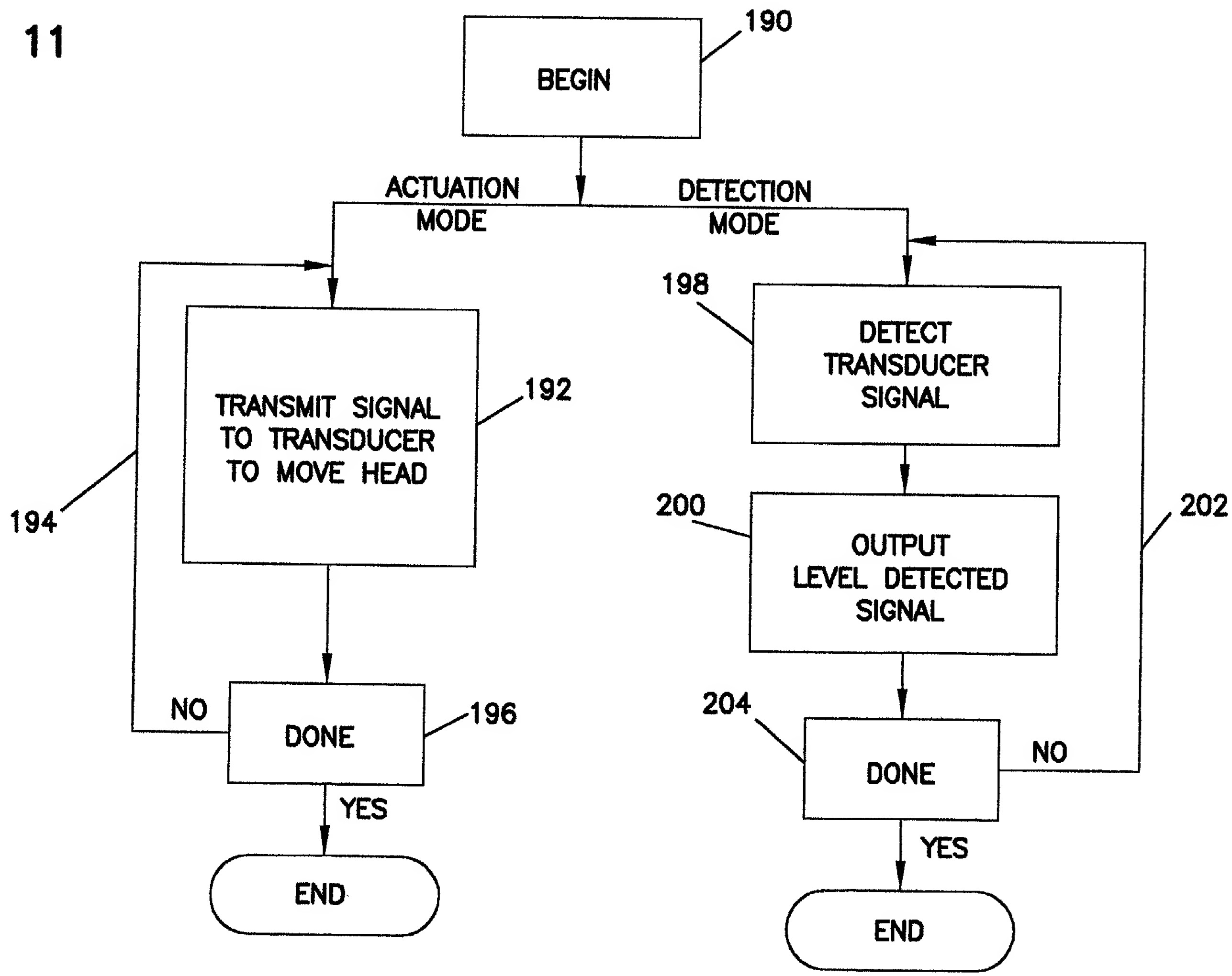


FIG. 11



BEGIN
190
ACTUATION MODE
DETECTION MODE
TRANSMIT SIGNAL TO TRANSDUCER TO MOVE HEAD
192
194
DONE
196
NO
YES
END
DETECT TRANSDUCER SIGNAL
198
OUTPUT LEVEL DETECTED SIGNAL
200
202
DONE
204
NO
YES
END

DECLARATION IN ORIGINAL APPLICATION	Attorney Docket No. S01.12-0543

SPECIFICATION AND INVENTORSHIP IDENTIFICATION

As a below named inventor, I declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and joint inventor of the subject matter which is claimed, and for which a patent is sought, on the invention entitled HEAD VIBRATION DETECTION DEVICE AND METHOD the specification of which,

(check one) _X_ is attached hereto.
__ was filed on as Appln. Serial No. .
__ and was amended on .
__ was described and claimed in PCT International Application No. filed on and as amended under PCT Article 19 on .

ACKNOWLEDGEMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is known to me to be material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56.

PRIORITY CLAIM (35 USC § 119)

I claim foreign priority benefits under Title 35, United States Code, § 119(a-d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Number	Country	Day/Month/Year Filed	Priority Claimed
____	____	____	Yes____ No____
____	____	____	Yes____ No____

Prior Provisional Application(s)

I hereby claim the benefit under Title 35, United States Code §119(e) of any United States Provisional Application(s) listed below:

Number	Day/Month/Year Filed
60/121,157	February 22, 1999
____	____

PRIORITY CLAIM (35 USC § 120)

I claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below. Insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 United States Code § 112, I acknowledge the duty to disclose to the Patent Office all information known to me to be material to patentability as defined in Title 37 Code of Federal Regulations § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Appln. Ser. No.	U.S. Serial No. (if any under PCT)	Filing Date	Status

DECLARATION

I declare that all statements made herein that are of my own knowledge are true and that all statements that are made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

DESIGNATION OF CORRESPONDENCE ADDRESS

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